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Subject: Contract RD-94
Task Order No. 2

[redacted]

In accordance with Article 2 of the basic contract, there are forwarded herewith two (2) copies of the Monthly Progress Report for May, 1957 on Task Order No. 2 of RD-94. This report is UNCLASSIFIED. An additional copy is being held in [redacted] by the project engineer for the use of your personnel while at this location.

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In connection with this monthly progress report, the following information is submitted:

Total expenditures to 4-30-57	$30,605
Outstanding commitments as of 4-30-57	135
Funds remaining as of 4-30-57	$29,576

Very truly yours,

[redacted]

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Assistant Manager
Government Contract Administration

TRR:mr
f-14608
Enclosures
cc: [redacted]

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Monthly Progress Report
May 1957

Task Order No. 2
Contract No. RD-94

Audio Noise Reduction Circuits

The object of this project is to develop a noise reduction circuit suitable for use in separating speech intelligence from a signal containing speech and noise when the speech intelligence is masked by the noise. The proposed method involves a principle which has been used successfully to improve the signal-to-noise ratio in music reproducing or transmission systems.[1] The system used for music contains bandpass filters which pass frequencies over a range of an octave or less. These filters are used at the input and output of a non-linear element. The output of the non-linear elements contain the fundamental, and also harmonics and subharmonics of the fundamental. However, since the pass band of the input and output bandpass filters is no greater than an octave, the harmonics and subharmonics are not transmitted by the system. The function of the non-linear element is to reject all noise signals below a given amplitude or threshold level. The threshold levels of the non-linear devices in each channel can be adjusted so that, in the absence of desired signal, the noise is rejected. When the desired signal is greater than the threshold level, the non-linear elements allow the composite signal to pass. Thus, for passages of recorded music, when the music signal is below the noise level in a given frequency channel, the channel is inoperative, and its output is eliminated from the total output. Since the contribution of this channel to the total output would have been only noise, the over-all noise level is reduced. When the

1. H.F. Olson, "Electronics," Dec. 1947.

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music signal in a given channel is greater than the noise, the channel conducts and allows the composite signal to pass. Thus, a channel conducts only when the desired signal is greater than the noise, and rejects when noise alone is present.

In order to apply this method of noise reduction to speech, when the wide band speech signal-to-noise ratio is very low, it was believed necessary to find frequency regions in which the speech amplitude is greater than the noise. Although the long time average spectrum of speech is continuous, and similar in shape to the spectrum of room noise,[2] the short time spectrum of various speech sounds contains regions of maximum energy called speech formants.[3] The assumption that this method of noise reduction should be utilized for speech was based upon the belief that it would be possible to find frequency regions in which the amplitude of the speech formants would be greater than the noise a substantial part of the time.

A study has been made to determine what bandwidths are required in order to obtain speech formant amplitudes above the noise when a wide band speech sample is just intelligible in noise. It is known that for noises with a continuous spectrum it is the noise components in the immediate frequency region of the masked tone which contribute to the masking.[4] When a very narrow band of noise is used to mask a pure tone, the masking increases as the bandwidth is increased until a certain bandwidth is reached. After this, as the bandwidth is increased, the amount of masking remains constant. This bandwidth at which the masking reaches a fixed value is termed the critical

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2. H. Fletcher, "Speech and Hearing on Communication," Van Nostrand Co., Inc., New York, 1953 (see Figures 61 and 70).

3. Op.cit. chap. 1.

4. L.L. Beranek, "The Design of Speech Communication Systems," Proc. IRE, Vol. 35, pp. 882, Sept. 1947.

bandwidth.[5] Measurements have been made using filters which were both narrower and wider than the critical bandwidth. Both pure tones and speech mixed with continuous spectrum type noises have been studied. The results of this study show that, for the narrowest permissible bands which can be used to pass speech formants, the number of times the speech formant amplitude in a given band exceeds the noise is small. Also, in these bands, the speech amplitude is never considerably greater than the noise. Since very narrow bandwidths are required to reduce the noise below the signal, the number of bands required to cover the speech spectrum is quite large. There was no satisfactory way of evaluating the effect upon speech intelligence of small contributions from many narrow bands without building a many channeled circuit and evaluating it.

In view of this fact a complete multi-channel system has been developed in order to determine the effectiveness of this method of improving speech intelligibility in noise. The multi-channel system developed contains 80 channels covering the frequency range from 700 to 3200 cps. The bandwidth of each channel is adjustable and each has been set so that it is one half that of the critical band when the signal is 3 db above the threshold level. A schedule of the band centers and their bandwidths is contained in the progress report for January 1957.

During May final adjustment and assembly of the 80 channel noise reducer was completed. A by-pass circuit was built which has the same pass band as the noise reduction circuit. The response-frequency characteristic of the by-pass circuit and the noise reduction circuit is shown in Figures 1 and 2. The input-output characteristic of the noise reducer at 1000 cps. is shown in Figure 3, Curve A. Some preliminary measurements have been

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5. N.R. French and J.C. Steinberg, "Factors Governing the Intelligibility of Speech Sounds," Jour.Acoust.Soc.Amer., Vol. 19, Jan. 1947 (see Figure 7).

made using this noise reducer on speech mixed with both flat noise and simulated room noise. In these measurements a recording of continuous discourse was played back through a mixing amplifier. The noise level mixed with the speech was adjusted until the threshold of intelligibility[6] was reached when the composite signal was passed through the by-pass circuit. The same composite signal was then passed through the noise reduction circuit at various levels above the threshold. A block diagram of the test circuit is shown in Figure 4. It has been found that when the maximum of the composite signal is about 5 db above the threshold some speech components are passed free of noise. However, the information contained in these components is not sufficient to provide speech intelligibility. It was found that the composite signal must be at least 15 db above the threshold in order to provide some intelligence, and maximum intelligence occurs when the maximum of the composite signal is from 20 to 25 db above the threshold of the noise reduction circuit. At this level both speech and noise are passed by the noise reduction circuit.

In order to maintain a more constant level for the maximum amplitude of the composite signal, a compression amplifier was added between the mixing amplifier and the noise reduction circuit. The response curve and compression characteristic are shown in Figures 5 and 6. The effect of the compression amplifier on the input-output characteristic of the noise reducer is shown in Figure 3, Curve B. The evaluation measurements were repeated using speech mixed with noise.

The results of these preliminary tests indicate that passing only the speech information which is greater than the noise does not provide sufficient

6. J.E. Hawkins, Jr. and S.S. Stevens, "The Masking of Pure Tones and of Speech by White Noise," JASA, Vol. 22, p. 11, January, 1950.

information to give speech intelligence. However, when the composite signal is 15 to 20 db above the threshold of the noise reducer, and considerable noise is passed, it is believed that the intelligibility of continuous discourse is improved.

In view of these results, it is planned to make further evaluation measurements and modifications of the circuit in an effort to improve its performance. Tests will be performed for various conditions of the noise reducer and noise samples. For example, the thresholds of the noise reducer channels can be adjusted as a function of frequency; the bandwidths of the channels can be adjusted; the characteristic of the compression amplifier can be varied. The results of these further measurements will give a better evaluation of this method of noise reduction.

ESR:pad
June 10, 1957

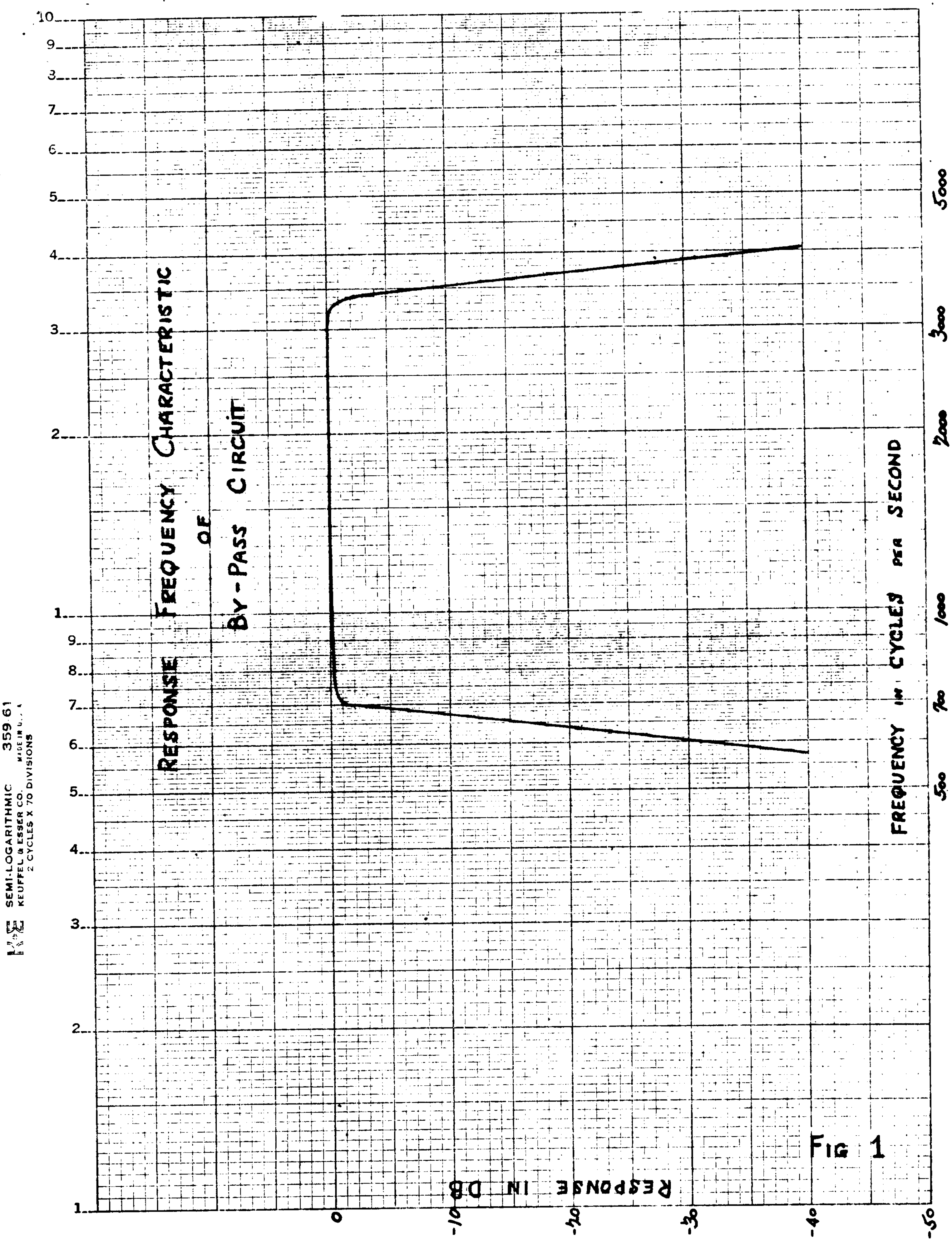
RESPONSE FREQUENCY CHARACTERISTIC
OF
BY-PASS CIRCUIT
FREQUENCY IN CYCLES PER SECOND
500
700
1000
2000
3000
5000
RESPONSE IN DB
0
-10
-20
-30
-40
-50
SEMI-LOGARITHMIC 359-61
KEUFFEL & ESSER CO.
2 CYCLES X 70 DIVISIONS

FIG 1

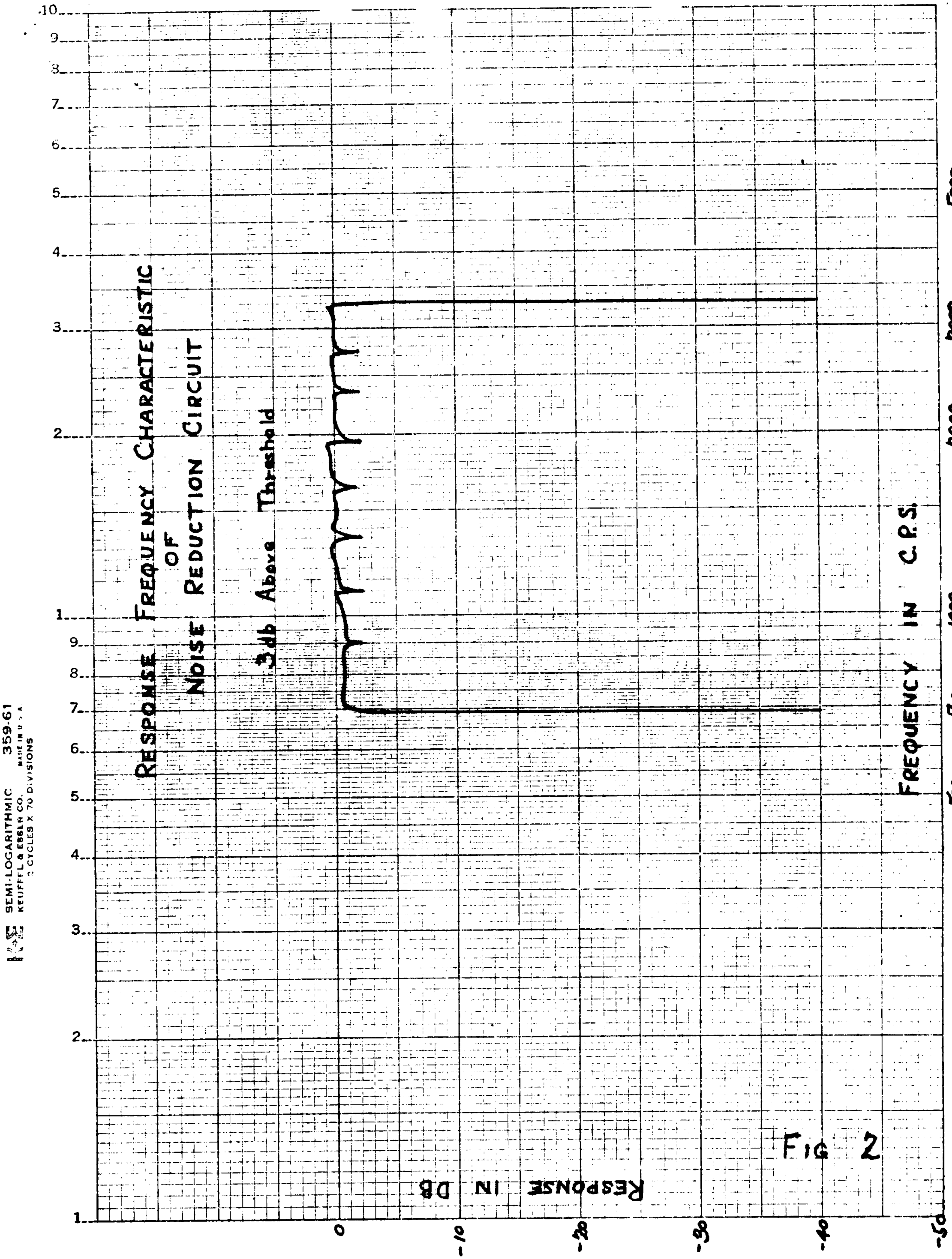

Fig 2

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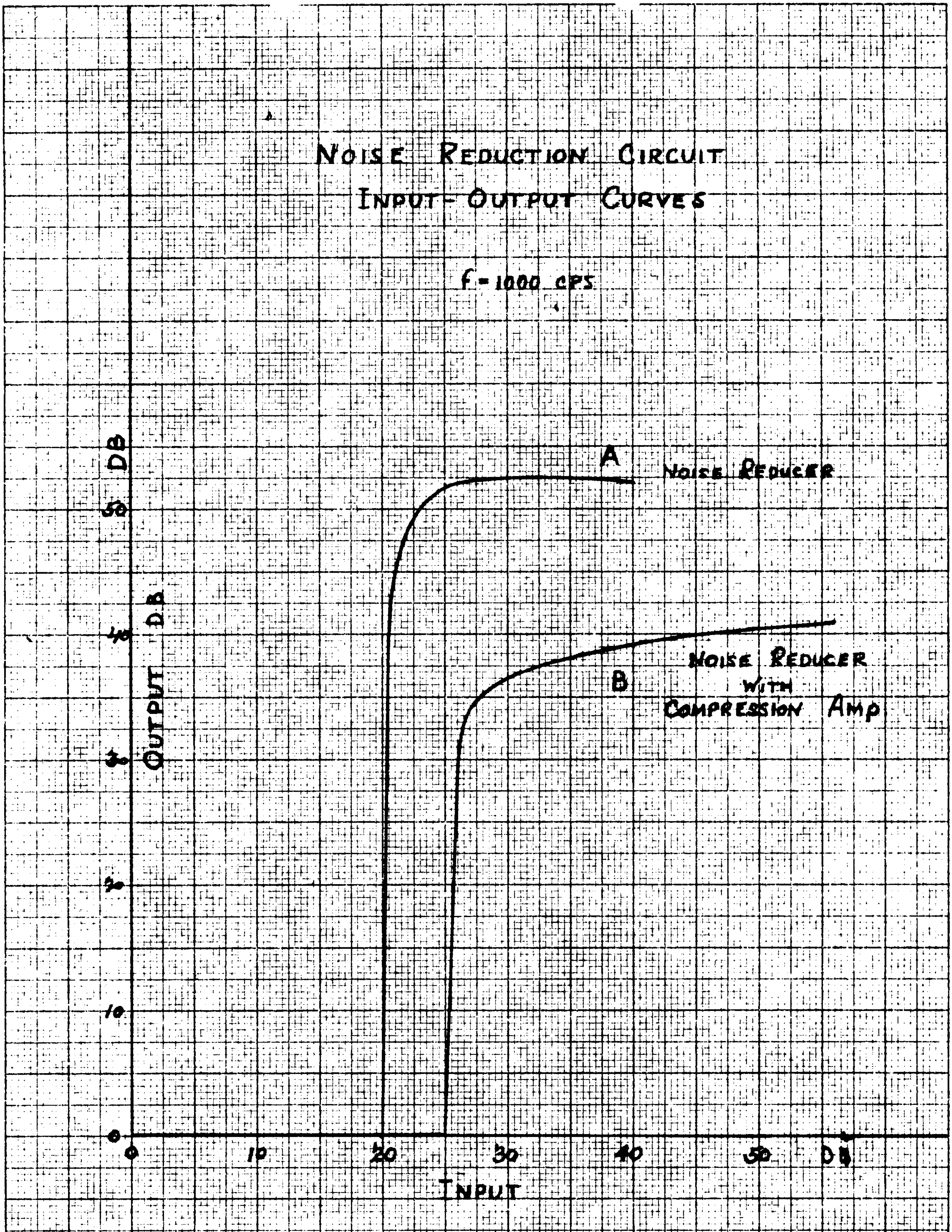
NOISE REDUCTION CIRCUIT
INPUT - OUTPUT CURVES
f = 1000 CPS
A
NOISE REDUCER
B
NOISE REDUCER
WITH
COMPRESSION AMP
OUTPUT D.B.
DB
50
40
30
20
10
0
0
10
20
30
40
50
DB
INPUT

FIG 3

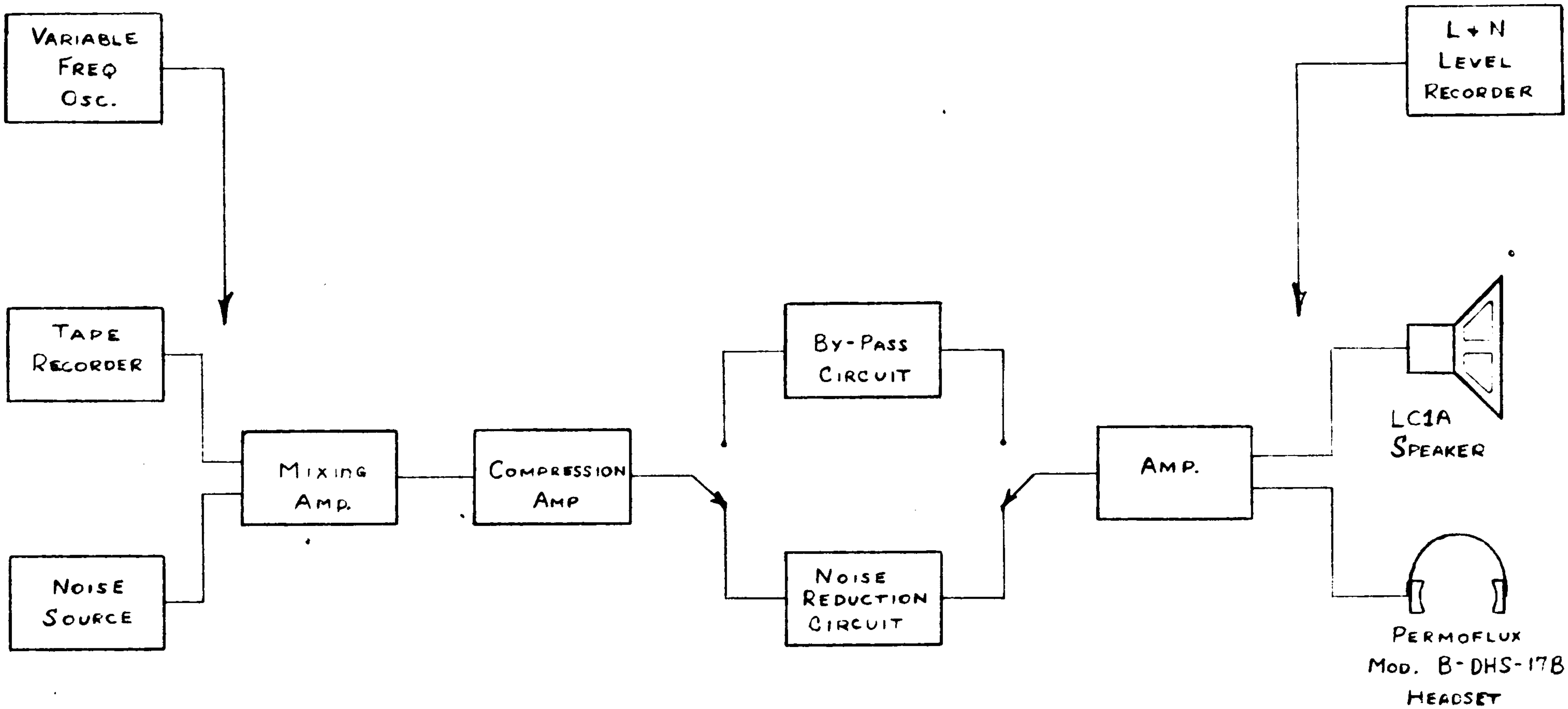

FIG 4 BLOCK DIAGRAM OF NOISE REDUCER TEST CIRCUIT

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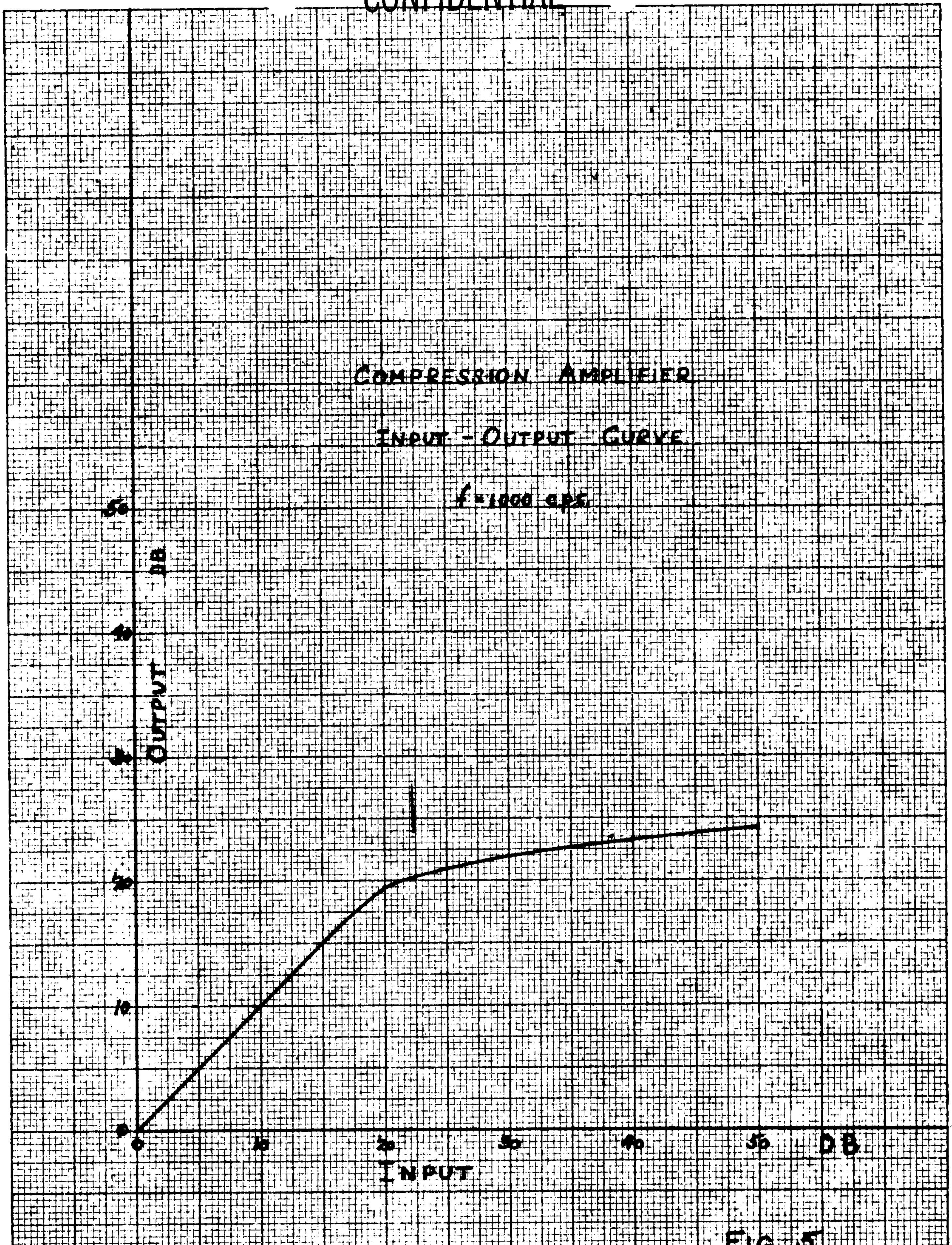
COMPRESSION AMPLIFIER
INPUT - OUTPUT CURVE
f = 1000 c.p.s.
OUTPUT DB
50
40
30
20
10
0
0
10
20
30
40
50
DB
INPUT

FIG. 5

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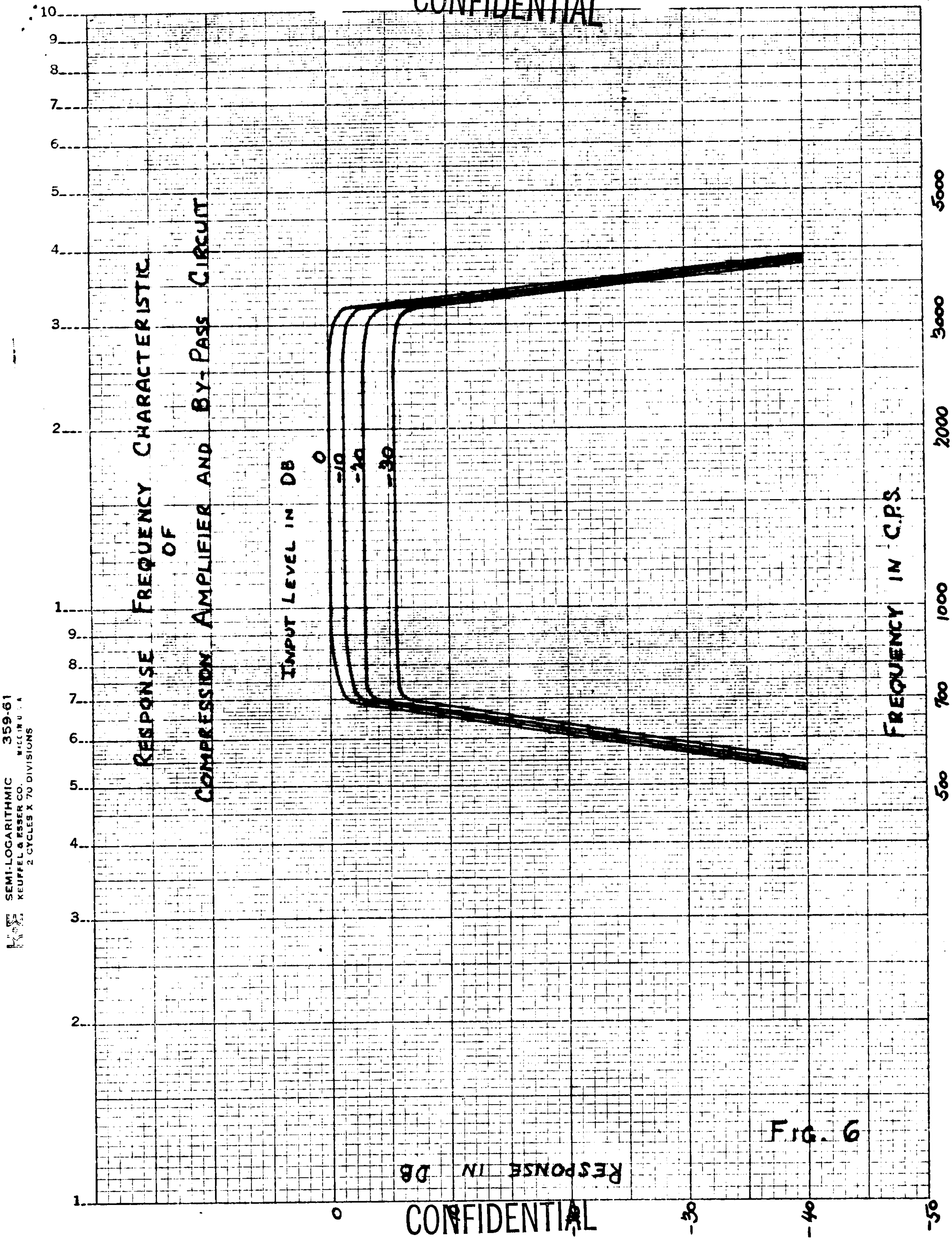

FIG. 6

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